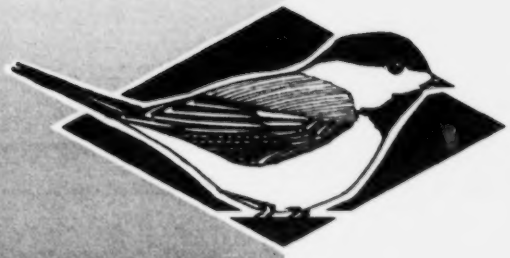

Fish & Wildlife Division

SPECIES AT RISK

A Habitat Suitability Model for Burrowing Owls (*Athene cunicularia*) in Alberta: Methods and Applications

Alberta Species at Risk Report No. 130

Government of Alberta ■

A Habitat Suitability Model for Burrowing Owls (*Athene cunicularia*) in Alberta: Methods and Applications

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EXECUTIVE SUMMARY

Declining populations of burrowing owls over the past several decades have led to the species being classified as endangered in Alberta and nationally. Population recovery is believed to be possible; however, there are several management issues and knowledge gaps that need to be addressed. The Alberta recovery plan for the burrowing owls lists protection and management of breeding habitat as important objectives for recovery, and the spatial identification of potential breeding habitat is the first step in the process.

We investigated home-range habitat selection by burrowing owls across the entire mixed prairie grassland region of western Canada to determine large-scale selection patterns, and examined potential links between high-use areas and reproductive success. Specifically, we classified 37 explanatory variables into five categories (geography, land-use, grassland fragmentation, soil, and climate), created models for each set of variables, and evaluated the predictive ability of each model. We also examined the link between high-use areas and reproductive success (i.e., nest survival and fledgling production), using the home-range habitat selection models as potential covariates. Our results showed that the all-inclusive, soil, and climate models were the most predictive of burrowing owl habitat selection at the home-range scale and that there was no relationship between the habitat selection indices and measures of reproductive success. Thus, owls are not selecting habitat that leads to higher (or lower) reproductive output.

This study provided one of the first spatially explicit descriptions of potential critical habitat for the burrowing owl recovery team. However, this research was designed only to narrow the potential areas within which critical habitat could be designated, which is one of the first steps in the identification process. This report addresses some of the limitations of the burrowing owl habitat suitability model and provides guidance for potential conservation applications, such as critical habitat identification and habitat stewardship. Specifically, we discuss species and environmental data limitations, and issues associated with the scale of the study and our definition of the available landscape. We also provide answers to the following questions:

1. *Does this map identify critical habitat for burrowing owls?*
2. *How can this map be useful for habitat stewardship programs?*
3. *How can confidence in the model be increased?*
4. *How can the model be used to help identify essential habitat for the burrowing owl?*

This report explains the utility of this habitat selection model for burrowing owl conservation and should reduce potential confusion about applying this model. Future studies could also incorporate fine-scale and more accurate data sources, different and multiple scales of selection, a population viability analysis, in-field surveys to evaluate the model, foraging and survival measures, model extrapolation, and direct measures of available resources (e.g., food, burrows) and limitations (e.g., predation risk).

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1.0 INTRODUCTION

The burrowing owl (*Athene cunicularia*) is classified as an endangered species (facing imminent extirpation or extinction) in Canada under the Species at Risk Act (COSEWIC 2006); also, it was recently up-listed from threatened to endangered status under Alberta's Wildlife Act (Endangered Species Conservation Committee 2006). This small (19.0–25.0 cm, 125-185 g), fossorial owl was once common across the four western provinces; however, Alberta and Saskatchewan are currently the only provinces supporting naturally-occurring, breeding populations (COSEWIC 2006). The Canadian Prairie population experienced an overall decrease of 90% in the 1990s and a range contraction of approximately 50% since the 1970s (COSEWIC 2006). Many biologists believe that widespread habitat loss and fragmentation resulting from the intensification of modern agricultural practices and increases in other human activities (e.g., oil and gas exploration) and their associated infrastructure (e.g., road networks, pipelines) are the ultimate causal factors for the population's decline (Wellicome and Haug 1995). As such, both the Alberta recovery plan (Alberta Burrowing Owl Recovery Team 2005) and the proposed national recovery strategy (Environment Canada 2010) for the burrowing owl list protection and management of breeding habitat as important objectives for population recovery. Identification of areas containing suitable breeding habitat is the first step towards actively protecting and managing the landscape for burrowing owls.

We created a home-range habitat selection model that predicts levels of breeding habitat suitability for burrowing owls across Alberta and Saskatchewan (Stevens 2008). This model was evaluated successfully with a temporally independent dataset, and was shown to be independent of reproductive success (indicating that areas with the highest densities of owls have the highest *total* production of offspring *per unit area*). In this report, we describe the utility of this model for burrowing owl conservation, examine strengths and weaknesses of the model and its underlying data, and provide guidance for proper use of the distributed end-product.

The specific objectives of this report are to:

- Present a brief overview of how the burrowing owl habitat suitability model was created, and illustrate the final mapped product for Alberta
- Provide an in-depth discussion on the limitations of this model and the recommended applications

2.0 STUDY AREA

The overall study area covered approximately 18 million ha in southeast Alberta and southern Saskatchewan, from the Canada-US border (49th parallel) to 52°50′N latitude and between 113°0′W and 103°30′W longitude; however, this report focuses on the Alberta region (Figure 1). This area is located within the Mixed Grassland ecoregion of the Prairie ecozone, which has a plant community dominated by medium-height grasses (e.g., needle and thread, *Stipa comata*), short grasses (e.g., blue grama, *Bouteloua gracilis*) and sedges (Trottier 1992). Agriculture, including cropping (irrigated and non-irrigated) and ranching (on native and non-native grassland), and oil and gas activity and

their associated infrastructure (e.g., roads, wells, compressors) dominate land-use in this ecoregion. Burrowing owls occupy this region from first arrival in mid-April until migration to their wintering grounds in September/October (Haug et al. 1993).

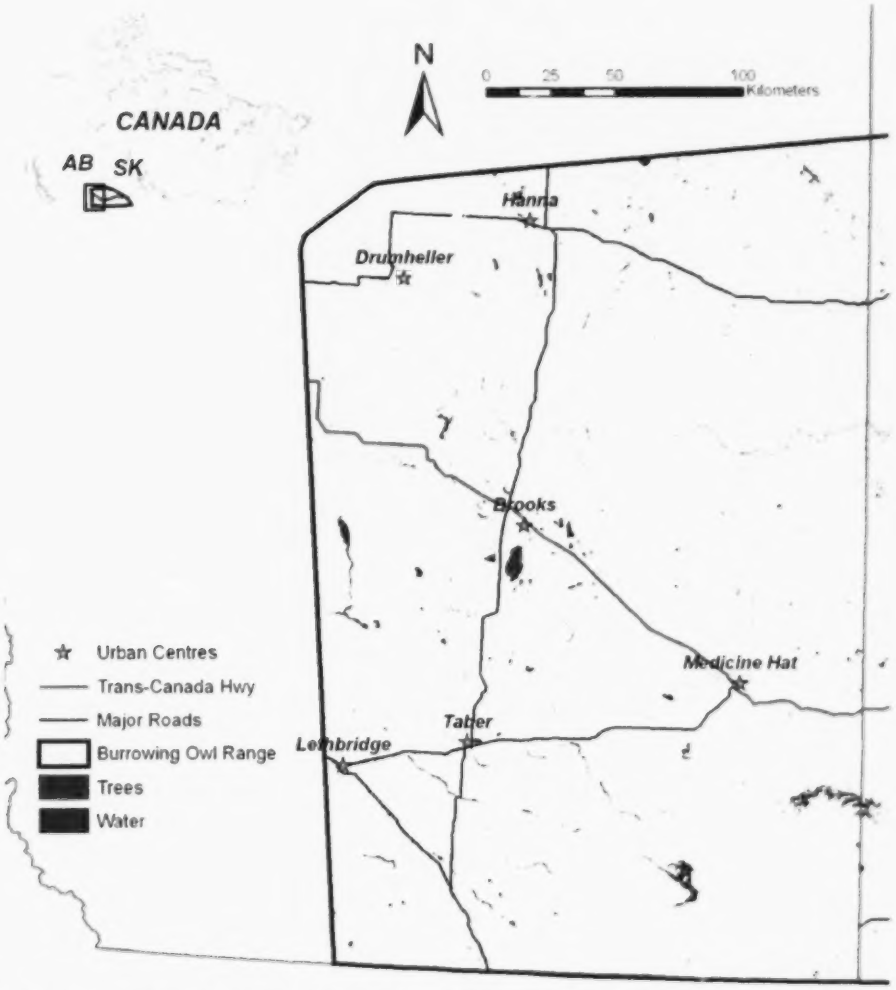

Figure 1. Project study area located within the Mixed Grassland ecoregion of south-eastern Alberta.

3.0 MODEL DEVELOPMENT

3.1 Species Data

Habitat selection models were developed with burrowing owl location data provided by a government wildlife database (i.e., the Alberta Fish and Wildlife Management

Information System), non-governmental organization databases (Operation Burrowing Owl and Operation Grassland Community) and with observations from independent sources. Data were constrained to the study area, and included points from 1987-2002. These data consist of presence-only observations, where observers detected burrowing owl presence either visually (i.e., observation, confirmed nest) or indirectly (e.g., pellets, whitewash, prey debris located near burrows). Resolution of the location data varied, with quarter-section (800 m^2, 64 ha) being the lowest; therefore, we randomly selected one 'used' point within each 'used' quarter section. To quantify the available landscape for model building, we generated random points across the landscape, excluding any water-bound areas, to provide a set of 'available' points.

An alternate set of nest location data was collected during a large-scale field project conducted by the Canadian Wildlife Service (CWS) from 2003-2006. Nests were located throughout the study area by visiting previously occupied sites, investigating new reports from conservation groups, landowners, land managers, field biologists, and from opportunistic observations. Spatial coordinates of owl nests monitored were recorded using Global Positioning System (GPS) units (accuracy ± 10m). Reproductive data was collected approximately once per week from all monitored nests located on public land (e.g., Prairie Farm Rehabilitation Administration pastures, Canadian Forces Base Suffield) and from nests on private land where landowners granted permission to access.

3.2 Environment Data

Environmental variables (n=37, Table 1) for the study area were summarized as spatial raster layers with a 30-m pixel resolution using ArcGIS 9.1 (ESRI 2004). For every spatial layer, each 30-m pixel summarized the environmental information within the neighbouring 1.2-km radius landscape, corresponding to the approximate maximum home-range size (mean 4.8 km^2) of male burrowing owls (Haug and Oliphant 1990).

These variables were classified into five groups: geography (elevation, slope, spatial location), grassland fragmentation (edge density, area-to-edge ratio, number of patches, mean patch size), land-use (proportion of crop, grass, hay, shrubs, trees, water, wetland; distance to water, wetland and tall woody vegetation), soil characteristics (dominant orders, parent material, texture; Soil) and climate (average precipitation, minimum and maximum temperatures for March, April, and May; Clim). These five classifications allowed for smaller sets of similar variables to be examined prior to creating an all-inclusive (All-Inc) model of burrowing owl home-range selection.

Table 1. Environmental predictor variables (n=37) used for burrowing owl habitat selection models in the Mixed Grassland ecoregion of Canada. The four letter codes identifying the five classes of variables are underlined in bold font.

Class	Code	Description and units	Data Source	Mean	SD
Geography	East[a]	false easting, m	Created using Spatial Analyst extension in ArcGIS 9.1.	384597	183006
	North[a]	false northing, m		192285	87757
	Elev	elevation, m	Digital Elevation Model (DEM) provided by Parks Canada (Swift Fox recovery team)[b]	772.3	136.4
	Slope	slope, degrees		1.775	1.784
Grassland **Fragmentation**	gEdge	grass edge density, km/km^2	Western Grain Transition Payment Program (WGTPP) landcover grid, Prairie Farm Rehabilitation Administration	2.124	2.748
	gPatch	number of grass patches		5.70	12.45
	gSize	mean patch size, km^2		1.305	1.701
	gRatio[a]	grass edge to area ratio		42.64	84.23
Land-Use	dTVeg[a]	distance to tall vegetation (trees & shrubs), m	Western Grain Transition Payment Program (WGTPP) landcover grid, Prairie Farm Rehabilitation Administration	2318	3440
	dWater[a]	distance to water, m		1744	1593
	dWet[a]	distance to wetlands, m		2599	3986
	pCrop	proportion of cultivated land		0.515	0.381
	pGrass	proportion of grass		0.400	0.374
	pHay	proportion of hay		0.025	0.080
	pShrub	proportion of shrubs		0.015	0.043
	pTrees	proportion of treed areas		0.003	0.025
	pWater	proportion of water		0.020	0.080
	pWet	proportion of wetland		0.016	0.031
Soil Characteristics	sCher	proportion of chernozemic order soils	Soil Landscapes of Canada v3.1, Agriculture and Agri-Food Canada. (Digital map and database at 1:1 million scale)	0.666	0.326
	sGley	proportion of gleysolic order soils		0.032	0.042
	sRego	proportion of regosolic order soils		0.045	0.135
	sSolo	proportion of solonetzic order soils		0.128	0.246
	sVert	proportion of vertisolic order soils		0.074	0.209
	pmEoli	proportion of eolian parent material soils		0.052	0.168
	pmFluv	proportion of fluvial (alluvial) parent material		0.079	0.164
	pmLacu	proportion of lacustrine parent material soils		0.258	0.322
	pmTill	proportion of till (moraine) parent material soils		0.494	0.364
	sText	categorical soil texture, from 1 (fine) to 7		---	---
Climate	Ppt3	average precipitation in March, mm	Worldclim database, version 1.4, http://worldclim.org	177.8	24.0
	Ppt4	average precipitation in April, mm		242.7	31.9
	Ppt5	average precipitation in May, mm		421.8	63.5
	Tmin3	minimum temperature in March, °C * 10		-101.7	12.5
	Tmin4	minimum temperature in April, °C * 10		-21.7	5.9
	Tmin5	minimum temperature in May, °C * 10		37.8	6.7
	Tmax3	maximum temperature in March, °C * 10		12.5	15.9
	Tmax4	maximum temperature in April, °C * 10		110.0	8.2
	Tmax5	maximum temperature in May, °C * 10		183.8	6.6

[a] *Variables were scaled down by a factor for all statistical analyses: 100 000 for East and North, 10 for gRatio, and 10 000 for dTVeg, dWater, and dWet.*

[b] *The Swift Fox DEM project relied on four data sources: Saskatchewan National Topographic Series 1:50 000 (NTS50) 20 m DEMs, Alberta NTS50 20 m DEMs, US Shuttle Radar Topography Mission (SRTM) 26 m (1 second arc), and SRTM 75 m (3 second arc).*

3.3 Statistics and Evaluation

A logistic regression Resource Selection Function (RSF; Manly et al. 2002) framework was used to model burrowing owl habitat suitability as a function of the five classes of environmental variables. We consider habitat suitability to be the relative probability of burrowing owl home-range selection (second-order selection; Johnson 1980). Used (1) and available (0) points were sampled at the population level (design I RSF), and compared using the logistic discriminant:

$$w(x) = exp\ (\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)$$

where w(x) is the RSF estimating relative likelihoods, and $\beta_1 \ldots \beta_n$ represent the coefficients estimated from a logistic regression model (Manly et al. 2002, Johnson et al. 2006).

Generalized Additive Models (GAMs) were used to determine the shape of the relationship between each individual environmental variable and owl use prior to multivariate analysis. We compared these univariate relationships of each variable to known burrowing owl ecology and incorporated different functional forms into the modelling framework. We found that the inclusion of correlated variables up to a maximum of 0.90 did not significantly alter the predictive ability of RSFs (Stevens 2008). Therefore, we calculated a Pearson correlation matrix between all variables to test for potential collinearity, and examined all models for inflated standard error estimates.

For each of the five classes of variables, two RSF models were created: the global model that included all variables and a final reduced and simplified model. We then combined all five simplified models to create the 'all-inclusive' model. We extrapolated this final RSF to the study area using ArcGIS 9.1 software (ESRI 2004) to produce a burrowing owl habitat suitability map depicting the relative probability of home-range selection in Alberta.

To evaluate the predictive capability of the model, we used the CWS dataset in conjunction with the evaluation method proposed by Johnson et al. (2006). Linear regression statistics (constant, β_0; slope, β_1; and R^2 value) and the χ^2 goodness-of-fit were used to compare the expected number for each bin *i* to the observed number of CWS points in each bin. If a model is approximately proportional to the probability of use, the linear regression constant will be close to zero and the slope will be close to 1.0. However, the predictive power is best described by the R^2 and the χ^2 goodness-of-fit tests, which assess the fit of the model. A model that accurately predicts observed values with the expected values will have high, positive R^2 values and a non-significant χ^2 value. R^2 represents the proportion of variance (or information) in the observed values that can be predicted from the expected values; whereas, the χ^2 statistic estimates how well the observed distribution of CWS points matches the expected distribution estimated by the statistical model. We also included the Spearman rank correlation statistic (Boyce et al. 2002) as another measure of predictive performance.

The final analysis of the model evaluated if burrowing owl home-range selection was linked to reproductive success (i.e., nest survival and number of fledglings produced), accounting for proximate factors that influence productivity at a given point in time. We created nest-survival and fledgling production models that included the habitat selection

indices generated in Stevens 2008 (Chapter 3) as covariates, while accounting for breeding season temporal dynamics and short-term precipitation variables. High precipitation is one of the most common causes of nest failure and nestling mortality in burrowing owls (Wellicome 2000; Wellicome et al., unpubl. data) and must be considered when evaluating how large-scale selection covariates relate to reproductive success.

4.0 RESULTS

4.1 Species Data

We assembled 3689 historical burrowing owl locations from the provincial data, from 1987 to 2002, and also generated a set of 70,783 random points that quantified the available landscape. Current in-field data collection for this project began in 2003, with 33 burrowing owl sites located and monitored in Alberta. In subsequent years (Figure 2), these sites were monitored for re-use, and new sites were also located and monitored, resulting in 271 monitored sites over four years, of which reproductive data could be collected at 245 sites.

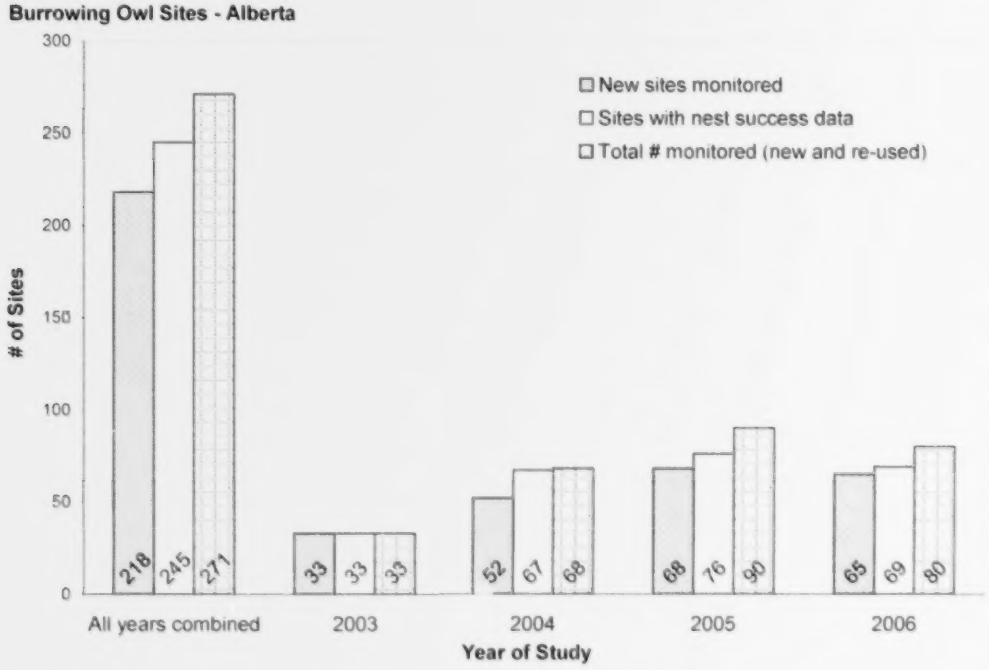

Figure 2. Burrowing owl locations and nest sites monitored over the four-year study period by the CWS project in Alberta, Canada.

4.2 Home-Range Habitat Selection

GAMs showed that the relationship between burrowing owl home-range selection and 35 of the 36 continuous environmental variables are described by non-linear relationships.

These non-linear relationships were incorporated into the all-inclusive model. The cultivated land variable (pCrop) was removed from the model because of its high negative correlation with grassland (pGrass; r = -0.94). Spatial predictions of burrowing owl home-range selection from the all-inclusive model in Alberta are shown in Figure 3.

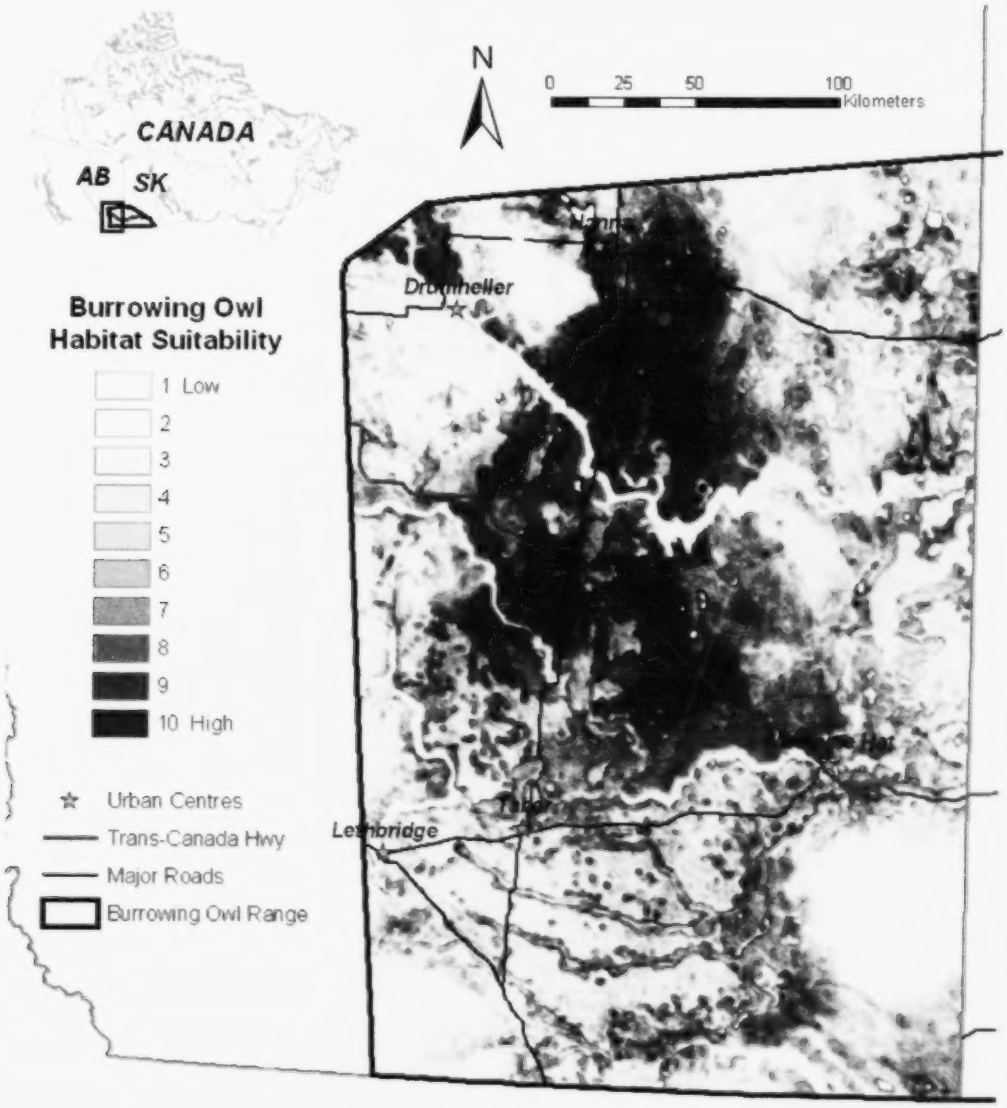

Figure 3. Relative index of burrowing owl home-range selection in the Mixed Grassland ecoregion of southern Alberta, Canada, created using logistic regression resource selection functions (RSFs). Values range from low suitability class 1 (light) to highest suitability class 10 (dark green), where high suitability indicates where a burrowing owl is most likely to select its home-range.

To summarize the all-inclusive model, within a 1.2 km radius, burrowing owls were associated with low, flat areas (β^2_{Elev}= -5.098; β_{Slope}= -0.352), low grassland edge densities (β_{gEdge} = -0.169) and moderate grassland patch size (quadratic relationship; β_{gSize}= 0.075 + β^2gSize= -0.039). Land-use distance variables were unimportant when all variables were considered. However, owls selected increasing proportions of grassland up to 0.25 of the 4.8 km^2 area, which then stabilized based on a breakpoint functional form (β_{pGrass_25bp}= 6.309). Owls also selected areas with a moderate amount of wetland as indicated by the better fit of a quadratic functional form (β_{pWet}= 17.315 + β^2_{pWet}= -75.404). Most soil variables remained important within the all-inclusive model, with owls associated with moderate proportions of chernozemic soils (quadratic function; β_{sCher}= 0.014 + β^2_{sCher}= -0.00015), decreasing levels of regosolic soils (β^2_{sRego}= -0.00027), increases in solonetzic soil up to 55% (breakpoint function; β_{sSolo_55bp}= 0.013), slight increases in vertisolic soils (β_{sVert}= 0.018), and moderate associations with fluvial parent material (quadratic function; β_{pmFluv}= -0.011 + $\beta_{0.5pmFluv}$= 0.091). Coarser, sandy soils were the preferred texture compared to finer, clay soils (β_{sText_6} = 0.665). Moderate minimum temperatures in March, April, and May, and moderate maximum temperatures in April and May were the variables most strongly associated with burrowing owl home-range selection. Model evaluation statistics are presented in Table 2.

Table 2. Evaluation statistics of the all-inclusive burrowing owl home-range selection model in the Canadian Mixed Grassland ecoregion, developed over the period 1987-2002. These statistics evaluate predictive accuracy by comparing model predictions (expected values) with out-of-sample CWS data (observed values) collected from 2003-2006.

		Goodness-of-Fit		*Linear Regression*			*Spearman (AAF)*	
	k	χ^2	P	R^2	β_0	β_1	R_S	p
All-Inclusive Model	62	31.87	0.0002	0.992	-0.008	1.077	0.964	0.000

In terms of reproductive success, we found that burrowing owl nest survival and fledgling production in the western prairies was largely independent of home-range placement. The all-inclusive, soil, and climate selection indices were each good predictors of burrowing owl use (see Chapter 3 of Stevens 2008), yet none of the top models for nest survival or fledgling production included these indices as predictive variables. Instead, precipitation and temporal (e.g., date, nest stage) covariates were the most important factors.

5.0 RECOMMENDATIONS AND LIMITATIONS

Effective breeding habitat designations require: 1) quantitative methods capable of creating spatially-explicit predictions; 2) recognition of spatial and temporal scale when making decisions about what habitat is suitable and essential; and 3) ecologically-based criteria for habitat needs that are linked to the main demographic factors that limit population growth in individual species. Stevens (2008) provides one of the first steps in this process by investigating second-order (Johnson 1980) home-range selection patterns for burrowing owls. This report illustrates Stevens' (2008) spatially-explicit model of

potential areas in Alberta within which population productivity per unit area can be maximized. In order to use these results effectively, we provide a discussion of the limitations and recommended applications of the all-inclusive habitat suitability model for burrowing owls.

5.1 Species and Environmental Data

To gather as much information as possible from such a large study area, a haphazard collection of burrowing owl location data was used to create the habitat selection model. This included data from biologists, landowners, oil and gas companies, non-governmental organizations and incidental observations from the general public. In an ideal scientific analysis, species presence data is gathered through systematic surveys conducted throughout the landscape, by trained biologists, to provide objective, accurate, and unbiased sampling. However, because these data were collected without a specified random or stratified sampling scheme, biases may be present in the data that might influence conclusions that are drawn.

For instance, burrowing owls near human land-use areas are more likely to be seen and reported, as opposed to owls that are located within large pastures less-frequented by humans. Also, oil and gas companies pre-survey for listed species along pipeline routes and well sites. This may lead to a greater number of owls known to associate with human land-use, creating a positive habitat selection coefficient. Though we did include large anthropogenic habitat-types, such as hayed land, we did not include linear and small anthropogenic features, such as roads, buildings, and pipelines, in the analysis of home-range habitat selection. Therefore, we avoided any spurious associations with these features; conversely, we were then unable to account for their potential influences.

In addition, an increase in the number of observers in certain areas can lead to an increase in detections and potentially to multiple counts of individual owls. We removed extra counts of owls by screening the dataset before model building, removing multiple counts by different observers in the same year within the same quarter-sections. On the other hand, this introduces an error of omission, as we may have deleted counts that were, in fact, independent within the same quarter-section.

This model is also necessarily limited by currently available environmental data. To examine finer scales of selection, researchers need to address the need for greater detail and spatial accuracy in the environmental data used. For instance, we may need to distinguish certain grass-species communities (e.g., pastures with native vs. introduced grass species) to determine which are preferred. As well, perhaps a smaller pixel size (5-10 m) will help differentiate important relationships from spurious ones. We recommend that all recovery teams and governments that are working in the same study region combine resources to create and provide accurate, detailed, and up-to-date spatial data within the grassland ecosystem. A carefully managed environmental geodatabase, preferably open-source, would be beneficial to all studies of species at risk in Alberta and Canada.

5.2 Scale and Availability

The objective for our study was to define overall selection patterns, and all covariates in Alberta (and Saskatchewan) were considered to be equally available to all owls when the available landscape was defined. Though soil and climate regimes were evenly distributed across the landscape, vegetation patterns were not. Myerstud and Ims (1998) noted that habitat selection can be conditional on availability, and therefore, the importance of vegetation cover types could be confounded by their availability on the landscape. Most of the intact, large parcels of grassland are found in south-eastern Alberta in association with large-scale ranching. However, all but south-western Saskatchewan is dominated by cultivated land, fragmenting the remaining grassland parcels and the entire landscape. To explore this relationship more explicitly, it may be necessary to separate the available landscape according to the dominant land-use practice, and review habitat selection accordingly. However, burrowing owls have the ability to disperse large distances among years (e.g., from one province to another; Wellicome et al. 1997), so the assumption that all habitat is available to all owls may be a reasonable one. If burrowing owls prefer landscapes with large amounts of grassland cover, they seem to have the ability to make that selection.

When attempting to link habitat use to habitat quality, home-range selection patterns were analysed only with respect to nest survival and fledgling production. These reproductive measures were a good starting point for a study of habitat quality in burrowing owls because some populations have been shown to be most sensitive to the production of young as opposed to mortality at older adult stages (Franken and Wellicome 2003). However, burrowing owl reproductive success within the Canadian Prairies is quite high (75-85% apparent nest success, with an average of 4.7 fledglings per successful nest; Stevens 2008). Therefore, other important demographic terms that were not measured may be closely related to variations in environmental variables and affect population persistence and growth; specifically, adult or juvenile survival in breeding, wintering, or migration areas. One of the most significant knowledge gaps at the moment is the migratory patterns and survival mechanisms of the Canadian population of burrowing owls.

Stevens (2008) found that the highest probabilities of home-range habitat selection, dictated by soil and climate variables, were not important to nest survival or fledgling production. This may be due to the scale at which these variables were examined. Both indices predicted habitat selection at the home-range scale of the owl itself, and not necessarily at the scales that are important to reproductive success, such as weather events and predation (Wellicome et al. 1997; Wellicome 2000). Weather events, particularly precipitation, are typically stochastic, and occur at different scales on the prairies. Conversely, predation risk could be modelled based on habitat; however, the scale depends on the predator, not the owl. A multi-scale analysis that incorporates ecologically-meaningful scales of potential predation events may show that habitat selection is actually correlated to reproductive success.

6.0 CONSERVATION MANAGEMENT APPLICATIONS

This final section of the report discusses practical questions end-users might have when presented with the model and map.

6.1 Does this map identify critical habitat for burrowing owls?

NO. The intention of this study was to provide a model showing areas with high habitat suitability for burrowing owls. The map shows 10 levels of habitat suitability based on **relative**, not absolute, probabilities of home-range selection. Therefore, this map is a relative index of habitat suitability, based on a quantitative analysis (as opposed to a qualitative Habitat Suitability Index based on expert opinion). There are many additional steps required to determine what highly suitable habitat is critical to Canadian owl populations.

In order to create the GIS map, the model was used to predict values across the entire study area (model-based interpolation to unsampled sites; Elith and Leathwick 2009). Within the study area (~180,000 km^2 across AB and SK), we surveyed ~10% of the land base from 2003-2006, with incidental coverage up to 30%, to obtain the data used to evaluate the model. This means that at least 70% of the land has not been surveyed for owls. Each habitat suitability category represents approximately 10% of the land base within the entire study area, and therefore ~126,000-180,000 km^2 within each category might not have been surveyed for owls. While we believe we have a representative sample of used points both for model building and model evaluation, additional surveys are needed within each habitat suitability classification to increase our confidence in the model.

Finally, this map provides indications of large areas of potential breeding habitat, but we still do not know how much of this land needs to be protected to ensure survival and recovery of the burrowing owl population. We examined two demographic measures, nest survival and fledgling production; however, a detailed population viability analysis should be combined with habitat selection models to provide a population estimate and growth rate. Aldridge and Boyce (2007) provide an example of such habitat population viability analysis using Resource Selection Functions; and recovery teams may use this as an approach to establish minimum land requirements for critical habitat designation.

a. *If category 10 is the most suitable habitat with the greatest number of owls within the study area comparatively, why can't it be designated critical habitat?*

Category 10 shows highly suitable habitat compared to lower classes; however, given the rarity of the species, the vast majority of land within category 10 remains unoccupied and has likely never been occupied by owls. Areas within category 10 cannot be assumed to be critical habitat without further quantitative evidence (e.g., actual species occurrence, either currently or at least historically within the prescribed recovery time frame). As well, we emphasize that the model only provides insight into second-order selection patterns (Johnson 1980). Though this was an area that was severely lacking in the published literature, future studies also need to increase our understanding of third- and fourth-order selection processes. Foraging and survival studies within home-ranges

should be useful for pinpointing a more definitive range of important habitat characteristics. As well, a key component for breeding habitat is density of burrows (Poulin et al. 2005), for nesting and roosting purposes. The distribution and availability of suitable burrows has yet to be examined, but this information is vital to identify critical habitat within predicted highly-suitable habitat. From a foraging perspective, additional research is required to discern which vegetation cover types and what vegetative structure is preferred by owls for prey capture. This will dictate habitats within home-ranges that need to be protected as critical for the owls.

b. If category 1 shows areas with low habitat suitability, do surveys still need to be conducted within those areas prior to development?

YES. This model is a relative index of habitat suitability, and classifies all land within the study area accordingly. Although category 1 shows areas that are of low suitability for burrowing owls (relative to the higher classifications), there are still recent verified records of nests found within this category, and within all categories. Therefore, we recommend that environmental assessment surveys still be conducted to locate any burrowing owls nesting within each area, regardless of classification by this model.

6.2 How can this map be useful for habitat stewardship programs?

This map can help to identify areas where more owls should be found per unit of search effort. For landowners who are keen to find owls but own a lot of land, this map may help direct landowners to quarter-sections that are predicted to be more suitable than others, in combination with knowledge of fine-scale habitat features that are required by owls but that are not currently quantified in a Geographic Information System (e.g., burrows, foraging conditions). As well, landowners with a lot of suitable land but no owls can be encouraged that their land management practices will still be beneficial if the population begins to increase and owls return to such land.

Nonetheless, locations of habitat stewardship projects should be based primarily on actual owl locations in the field, though higher priority might be considered for conservation work that occurs in areas of high suitability identified by this model. Category 10 indicates potential areas to survey for owls, but should not limit stewardship goals. As stated above, burrowing owl nests have been found in all levels of habitat suitability. Therefore any owls that are found by landowners who are willing to participate in habitat stewardship programs could benefit from a habitat enhancement project and financial assistance, particularly if the project creates more suitable habitat for burrowing owls.

6.3 How can confidence in the model be increased?

Ideally, systematic surveys for owls would be performed across the entire study region, and owl presence and absence data overlaid onto the map to test model predictions. However, the completion of such a large survey is difficult, given limited resources and logistic constraints. Therefore, the habitat selection map in this report can be used to create a stratified sampling design to minimize the high-costs associated with surveying this rare species across a large study area, and thus test model predictions.

Another way to test the model is through extrapolation to a new area, using a spatially-independent dataset to test model predictions. For example, this model was built using data from Alberta and Saskatchewan; however, Manitoba also has a small current and historical population of owls. Extrapolating the model to Manitoba and overlaying the known owl locations could provide additional insight into the predictive powers of this model. Careful consideration of the environmental data (similar datasets and ranges of values) is important to any such extrapolation.

6.4 How can the model be used to help identify essential habitat for the burrowing owl?

Like all Species Distribution Models that quantify the relationship between species and their environment using empirical data (Guisan and Zimmerman 2000, Johnson and Gillingham 2005), this model is correlative in nature and causal relationships are not explicitly tested in the model. However, this does not exclude commentary linking the model statistics to the ecology of the species by examining environmental features identified as important (i.e., environmental characteristics associated with high relative probability of home-range habitat selection). For instance, our results demonstrate selection for coarse-textured, sandy soils, and avoidance of finer, clay-like soils. This may be due to soil conditions being a surrogate measure for burrow availability, which is a necessity for essential breeding habitat. While we did not explicitly test for this relationship, the model provided insight into the importance of soils, and may guide additional studies that test for a causal relationship (see Stevens 2008 for further discussion).

Future studies should also quantify why certain habitats are selected, by including direct measures of available resources (e.g., food) and limitations (e.g., predation risk), and also determine exactly what resources at which times influence productivity. For instance, foraging studies that define third-order habitat selection within the home-range (Johnson 1980) should incorporate what resource items are being used and when they are being used optimally and link these directly to measures of reproductive success. To further assess habitat quality, more demographic terms, such as adult survival and juvenile post-fledging survival, should be related to habitat characteristics.

7.0 CONCLUSIONS

The purpose of this report was to document practical issues and potential misinterpretations in applying the habitat suitability model for burrowing owl management actions. It is important to provide proper communication to interested end-users of a statistical model and map created for an endangered species. We hope that this report (and the detailed work from which it was derived [Stevens 2008]) will answer many questions and reduce confusion about applications of these products.

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